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OPEN SOURCE INNOVATION: TOWARDS A GENERALIZATION OF THE OPEN SOURCE MODEL BEYOND SOFTWARE

Key words: Open source innovation, free-libre software, open innovation, patents, collective invention.

Mots-clés: Open source, logiciel libre, innovation ouverte, brevet d'invention, invention collective.

I. — INTRODUCTION

In the software industry, the success of the principles that guide the open source movement can hardly be denied. The combination of a bazaar mode of organization (Raymond, 1999), of open disclosure of source codes and of a copyleft type of legal licenses has provided a very successful recipe for producing reliable software in a very short spell of time. This initial success of the open source model in software development raises the issue of the relevance of exporting it to other sectors (Burk, 2002; Maurer, 2003; Hope, 2008). Lakhani and Panetta (2007, p. 98) explain for instance that: « The achievements of open source software communities have brought the distributed innovation model to general attention so that it is rapidly taking hold in industries as diverse as apparel and clothing, encyclopaedias, biotechnology and pharmaceuticals, and music and entertainment ».

The objective of this paper is thus to explore whether the general principles that guide the production of free-libre-open-source-software (we shall use the acronym FLOSS in the remainder of this article) can be applied with the same success in other sectors. The layman's immediate answer to this question is that it has already been theorized: the concept of open innovation introduced by Chesbrough (2003) accounts for the extension of FLOSS to sectors other than software development. We have already emphasized the fallacy of this answer in previous publications and stressed the important differences between the open source phenomenon and open innovation (Pénin, 2009).

In this paper, therefore, we propose a general definition of open source innovation (or « OSI ») that is sufficiently broad to encompass not only FLOSS but also other open source-like production model observed in sectors other than the software development industry. Our approach is inductive. We start from the observation of the key principles that govern the functioning of FLOSS and show that these principles can be applied in other fields. Obviously, many features are specific to software production and do not make sense beyond this field. But overall, we show that the broad principles underlying FLOSS can be exported to other sectors.

Our definition of OSI is based on the recipe on which the success of FLOSS rests : the « bazaar » type of organization and the openness of knowledge. We argue that an innovation process can be considered open source if it has, during a significant period of time, the three following properties : the actors of the innovation process (firms or individuals) voluntarily disclose knowledge ; knowledge is « open », which means that its disclosure is not limited to specific beneficiaries ; there are continuous interactions between the actors of the innovation process. Furthermore, we also suggest that it may be necessary to use intellectual property rights (IPR), and specifically patents, in order to guarantee the openness of the innovation process (Boettiger and Burk, 2004 ; David, 2006). Indeed, the FLOSS example shows that a specific use of IPR, in a copyleft fashion, can help preserve the openness of the source code, thus fostering exchanges and collaboration among developers.

Having provided a definition of OSI, we then investigate the specific contexts in which open source knowledge production processes can be successful, *i.e.* in which case the open source model can replace the proprietary model based on exclusion. For this purpose, we link OSI to the dynamics of the innovation process. In particular, we argue that the emergence of OSI settings is all the more probable as the context is « emergent » (Callon, 1999). In other words, OSI might not replace the proprietary model but rather co-exist with it : OSI settings may serve as a reservoir, an upstream knowledge platform that firms can openly use to develop end-products and to compete on downstream markets.

The next section (section 2) defines OSI. The third section outlines the differences between OSI and open innovation *à la* Chesbrough (2003). The fourth section explains why and in which context the OSI model might be successful in sectors other than software. Finally, in the fifth section we provide two examples that fit this OSI model. We consider the case of BiOS, which constitutes an attempt to develop a framework of open source biology in the field of agronomics (Hope, 2008 ; Pénin and Wack, 2008) and the case of creative industries (Bach *et al.,* 2010).

II. — A DEFINITION OF OPEN SOURCE INNOVATION

2.1. Definition

Since our definition of OSI is a generalization of the open source model in the software sector, it makes sense to start with a reminder of the broad principles of FLOSS. The extensive literature that has analysed the functioning of FLOSS in the past decade puts forward three core dimensions : technical, legal and organisational (Raymond, 1999 ; Lerner and Tirole, 2001 ; Bonaccorsi and Rossi, 2003 ; Dalle and Jullien, 2003 ; Lakhani and von Hippel, 2003 ; Lakhani and Wolf, 2003 ; Henkel, 2006).

— At the technical level, FLOSS are released with their source code. Within FLOSS projects participants deliberately and freely release their production (lines of code mostly), which is made available to everybody without discrimination. The diffusion of the source code is thus fundamentally open since it is not restricted to members of the project but is made available to all.

— At the organisational level, FLOSS are developed following a loose organization called agora or bazaar (Raymond, 1999). This mode of development differs from the traditional, in-house conception of software, based on hierarchy, secrecy and control, and which is compared by Raymond to the building of Cathedrals. In a bazaar type of organization, hundreds of developers constantly interact in order to improve the code released by other developers. Improvements are, in turn, also released so that everybody can validate and, again, modify them. This collective and communitarian mode of development, coupled with the open disclosure of source code emphasized above, has proved very efficient. The open collaboration of developers on a large scale implies that FLOSS are designed and debugged in a short time (it is the so-called Linus' law).

— At the legal level, FLOSS are software protected by original licenses that prevent the exclusive appropriation of the software and of its subsequent modifications (de Laat, 2005). Indeed, open source projects use a variety of licenses, more or less based on the copyleft principles introduced by the pioneer GPL license, in order to forbid the closing of the source code. Typically, the license stipulates that everybody can use, modify, copy and even distribute software « protected » by copyleft on the unique condition that any change is protected by the same system (*i.e.* the source code of the improvements must also be copylefted). The license therefore spreads like a virus. Any user who modifies the software and wishes to distribute his modified version needs to do so under the copyleft licence in question.

Those three dimensions (technical, organizational and legal) follow a logical order that can be explained as follows : the objective of most FLOSS projects is to promote a bazaar mode of software development, which is considered by many as more efficient. Yet, this bazaar-style organization requires that source code is openly available. Thus, the technical dimension is necessary to ensure the sustainability of the organizational dimension. And, in turn, the legal dimension (copyleft type of protection) serves to ensure the full availability of the source code. To put it differently, viral licenses, which are used in most FLOSS projects, are intended to ensure openness and interactivity. The legal dimension is therefore not constitutive to open source. It is a « support mechanism », an instrument aimed at preserving the openness and interactivity, which constitute the two pillars of the open source model.

Generalizing the main principles of the FLOSS model enables us to propose a definition of OSI that rests on two properties: openness and interactivity. We suggest that, in order to qualify as « open source » an innovation process (1) must have, during a significant period of time, the three following features.

(i) Actors of the innovation process voluntarily disclose the knowledge (technical or not) they produce (*i.e.* knowledge in our general setting corresponds to source code in the specific case of FLOSS).

(ii) This knowledge is « open » in that it must be available not just to some specified beneficiaries but to everyone without discrimination (*i.e.* once they are produced, spillovers are not controllable by the sender, West and Gallagher, 2006) (2).

(iii) Actors of the innovation process interact in a bazaar mode, meaning that the open disclosure of knowledge initiates a long lasting chain of exchanges and collaborations in order to enrich the open knowledge base (*i.e.* knowledge disclosure is continuous and is not the work of one single individual at a single point in time).

(1) It is important to keep in mind the central distinction between a process and a product. Both can be open source but our definition of open source clearly deals with the process of innovation and not with a single product. To quote Weber (2004, p. 14): « Linux will not last forever […] Remember what is potentially durable and possibly deserving of the term "revolutionary" – not a particular manifestation of a process but the process itself » (p. 14) […]. « The essence of open source is not the software. It is the process by which software is created. […] If I were writing this book in 1925 and the title was *The secret of Ford* I would focus on the factory assembly line and the organization of production around it, not about the cars Ford produced. Production processes, or ways of making things are of far more importance than the artifacts produced because they spread more broadly » (Weber, 2004, p. 56).

(2) As has been shown in the software case, this open dimension is an efficiency condition. It is only when knowledge is open that one can guarantee its optimal use. Everybody must have the opportunity to use knowledge in order to improve it, enrich it and put it back into the open pool. Barriers that would impose some control over the pool or over elements of it would decrease the efficiency of this process of knowledge enrichment (Lakhani *et al.,* 2007; Murray *et al.,* 2009).

Our definition implies, first of all, that firms and individuals involved in OSI really intend to share and to release knowledge, so that knowledge flows cannot be attributed to undesirable externalities. In other words, spillovers are endogenous (Katsoulacos and Ulph, 1998 ; Pénin, 2003).

The second implication was discussed extensively in a previous paper, in which we proposed a definition of openness for knowledge and technology (Pénin, 2009). We argued that a piece of knowledge is open if it is made available to all either for free (this condition is what we call the strong definition of openness) or under conditions that are not discriminatory and not prohibitive (the weak definition). All interested parties must be given access to the knowledge, which therefore does not belong to just one or several individuals who would then control other parties' access to it. In other words, an open technology is one that has no owner or one whose owner has waived his/her right to control access. « Open knowledge » must therefore be distinguished from knowledge that is accessible « free of charge ». A technology may be « open » but not free of charge, if the fee to access the technology is considered reasonable (Pénin, 2009).

The third requirement for an innovation process to be considered « open source » is related to the interactions among the participants. It is important to differentiate between a situation in which actors would just disclose knowledge at one point in time (spot disclosure) and a situation in which firms regularly disclose knowledge, use knowledge disclosed by other firms, disclose again their improved knowledge, etc. In short, in OSI frameworks, participants develop dynamic interactions in order to continuously improve and enrich the open knowledge base. This requirement is in line with that mentioned by Maurer *et al.* (2004), who tried to define open source biology and argued that it should be a « decentralised web-based, community-wide effort, where scientists from laboratories, universities, institutes, and corporations could work together for a common cause » (Maurer *et al.,* 2004, p. 183). Clearly inherent in this definition is the necessity for frequent interactions and collaborations between as many diverse participants as possible.

Our definition of OSI therefore centres around two main dimensions : openness of the produced knowledge and constant interactions between the actors of the innovation process (3). OSI defines a fundamentally open and interacti-

(3) Our definition of OSI is very similar to what von Hippel (2005, p 93) calls « innovation communities » and to what Shah (2005) calls « community based innovation » : « In stark contrast to the proprietary model, the community based model relies neither on exclusive property rights nor hierarchical managerial control. The model is based upon *the open, voluntary, and collaborative efforts of users* » (Shah, 2005, p. 2, Italics are mine). Yet, the word « community », although appropriate to stress the multiple and ongoing interactions among participants, does not emphasize the open nature of the process. It suggests a frontier between insiders and outsiders of the community. The expression « open innovation communities » or « open information communities » may therefore be more adapted.

ve process. Actors in this process develop a dynamic process of collaboration in order to build an open resource (a technology, software, etc.). Thus, the three conditions that we have described are equally necessary: an innovation process that does not operate under these three conditions cannot be considered « open source » (4).

Many examples in the past as well as in recent history fit our definition of OSI. First of all, « user centred innovation » introduced by von Hippel in the past two decades often meets the criteria of OSI (5). Open science, as it was implemented after WWII, is also an attempt to develop and to institutionalize an OSI model for the production of upstream, fundamental knowledge (Stephan, 1996). Finally, collective invention as introduced by Allen also clearly fits in with our definition of OSI (Allen, 1983; Nuvolari, 2004; Osterloh and Rota, 2007).

To conclude, depending on the contexts, OSI situations can emerge over a long period (as in the case of software) or on a more « once off » basis, for instance in the context of a specific project, at the end of which the innovation process becomes closed again, because the project stops or because participants decide to leave the community. However, in any attempt to develop OSI frameworks one cannot ignore the issue of IPR which, as it has been shown in the case of software, play a critical role in maintaining the openness of the process.

2.2. IPR's legal jujitsu

The FLOSS example does indeed suggest that, far from being a threat to openness, IPR, and patents in particular, may be necessary to sustain OSI (Pénin and Wack, 2008). Indeed, patents are flexible tools that can serve different purposes, depending on the objectives of their holders: they can exclude imitators but they can also, at the other extreme of the spectrum, prevent exclusion (Cohendet *et al.,* 2009). Consequently, patents may become important instruments for OSI participants in order to make sure that the knowledge and technologies produced are made available to all and that subsequent improved versions are also accessible.

(4) This implies that, in practice, many FLOSS projects do not fit with our definition of OSI. It is indeed well-known that in many cases, FLOSS projects do not interest more than a couple of isolated developers, and sometimes only one. Therefore, the source code is made open under copyleft, but the process never starts. In this case, the innovation process is potentially open source but this potentiality does not become effective.

(5) Within a user centered context of innovation, users voluntarily disclose knowledge, this disclosure is most of the time open, and it triggers an ongoing chain of feedbacks and improvements among users and manufacturers. As acknowledged by von Hippel (2005, p. 10): « Users who freely release what they have done often find that others then improve or suggest improvements to the innovation, to mutual benefit ». Examples of such user centered innovation are the development of high performance windsurf techniques and equipment in Hawai, the free-libre open source software movement, the development of mountain bikes, etc.

More precisely, it may be necessary to rely on copyleft types of licenses in order to ensure that nobody can appropriate fragments of the open knowledge base. Indeed the OSI model implies that the users of the open knowledge pool will voluntarily release their new knowledge into the pool. Yet, knowledge being open and thus accessible to all, outsiders might try to appropriate new pieces of knowledge designed in the open platform. Those outsiders cannot in theory patent the knowledge created within the open source project because it is in the public domain. Yet, what they are allowed to do is to improve this knowledge and to appropriate the improvements, thus introducing boundaries into the open space. Such behaviors clearly threaten the dynamics and therefore the viability of OSI. To prevent this from occurring, one can envisage using IPR and patents particularly, in a « legal jujitsu » logic (Benkler, 2006) (6) as in the case of software development (David, 2006; Hope, 2008). This original and counter-intuitive use of IPR may thus prove necessary to promote the effect of enrichment of the open knowledge pool, an effect which is at the heart of OSI.

Practically, and as in the case of FLOSS, the open source use of patents is based on licenses that contain grant-back provisions. Depending on the nature of the product developed by the community, the open knowledge base can be protected by patents, copyrights or other kinds of IPR. Yet, unlike in the case of the traditional use of IPR, the community can waive its right to control access to the technology it has produced by granting licenses, either for free or for a small fee, to all those who wish to. The only requirement to access the knowledge is then to commit to license any improvement back into the open pool. To put it differently, users of open source technologies are granted a license only if they agree to share any alteration they might make to the technology with its creators and to keep it in the « free » regime so that the knowledge and technology remain open and available to all those who agree with the licensing terms. In the case of patents, this solution is equivalent to creating an open patent pool (Pénin and Wack, 2008). Compared with these open source licensing practices, the publication of knowledge into the public domain does indeed make this knowledge freely accessible but does not ensure that subsequent improvements made to this knowledge will also be freely accessible. Those strategies entail the risk that follow-on innovators appropriate part of the open knowledge base and therein control its use.

To sum up, appropriate licensing contracts, based on the copyleft principle, might enable patent holders to prevent exclusive appropriation by third parties,

(6) This analogy with jujitsu has been made by Benkler (2006). Jujitsu is a martial art oriented towards active self-defense. Jujitsu practitioners are never offenders but once they are attacked they practice a pro-active and offensive defense. Having developed several skillful techniques, they are experts in using the strength of their adversaries to their advantage. Similarly for OSI patent owners use the strength of the patent system against its primary purpose. In line with the state of mind of martial art practitioners, open source tenants use IPR to prevent that entire streams of research are closed down by aggressive appropriation strategies.

in given technological fields or to impose certain specific uses to licensees concerning, for instance, the price and the quality of their products, or the required level of diffusion. Those terms are useful in particular for universities, which might attach particular importance to the issue of dissemination of knowledge and research results (Pénin, 2010). Open patent and copyleft-type licenses might therefore enable universities to prevent the exclusive appropriation of some technologies they have contributed to develop or, at least, to ensure, to some extent, that the technology in question is used in the general interest.

The Insulin patent applied for in 1922 by the University of Toronto is a perfect example of how a patent can ensure the openness of a technology and of its improvements (Cassier and Sinding, 2008 ; Pénin, 2010). Against the norms of the scientific community at the time, the University of Toronto decided to patent Insulin. It did so not in order to favor the emergence of a monopoly but to protect the quality of insulin production and ensure its wide accessibility (7). The University of Toronto decided therefore to grant a non-exclusive license to all firms who agreed to follow specific good manufacturing practices. Furthermore firms also had to agree to release any improvements they made (in particular those related to the manufacturing processes) into the open pool set up and controlled by the university. This open patent pool was active for almost 30 years, from 1923 until WWII. It guaranteed wide access to the molecule and to improved insulin products. The Insulin patent is therefore, to some extent, the ancestor of the copyleft practices that are now common in the software industry.

How well do these viral, copyleft licenses perform their function of supporting OSI ? This issue was studied by Gambardella and Hall (2006), who stress two opposite effects. On the one hand those licenses may trigger more participation to the development of the OSI because some contributors, who could have envisaged contributing under a private patent regime, are now constrained by the term of the license to contribute in an open way. But on the other hand, since the license restricts contributors' rights, it may also deter some of them from contributing at all, whereas they would have agreed to contribute in a more closed, proprietary regime. Thus, the desirability of these copyleft-type licenses is a function of two counter-balancing forces. In particular, the negative effect emphasized by Gambardella and Hall stems from the fact that some contributors may be frightened by the restrictive terms of the license which, in the end, may decrease the overall rate of participation and hinder the development of the innovation. For instance, in the case of software, it seems that the more restrictive the open license, the lower the probability of achieving a stable mature software product (Comino *et al.,* 2007).

(7) According to Cassier and Sinding (2008, p. 156) : « In addition to its role of preventing a commercial monopoly, the patent gave the university the authority to set the standards of the new drug, control the quality of its industrial production, and regulate the condition of its marketing. In the university's hands the patent was a tool to discipline the industrial world, to organize the distribution and use of the new drug, and to guarantee its accessibility ».

III. — OPEN SOURCE INNOVATION VERSUS OPEN INNOVATION

OSI is often mistaken for open innovation, a concept introduced and popularized by Chesbrough (2003) and which has given rise to abundant literature in organization sciences. Yet, the open source mode of knowledge production entails very different properties (8). In this section, we show that OSI and open innovation differ with respect to the two central dimensions of OSI: the degree of openness and the degree of interactivity.

The concept of open innovation requires that firms open up their boundaries and encourages them, on the one hand, to acquire knowledge and technology developed elsewhere (through in-licensing, firms' acquisition and alliances) and, on the other hand, to export knowledge and technologies developed inside (through out-licensing, spin-offs and alliances) (9), (10). The practice of open innovation relies therefore on two types of knowledge flows: outside-in and inside-out. Firms absorb technology developed by other organizations (outside-in) and export technology developed inside (inside-out) (Pénin *et al.,* 2011).

Isckia and Lescop (2010) argue that open innovation can be considered as a new concept only with respect to the inside-out idea. Here, open innovation goes hand in hand with other trends that have emerged recently: the development of markets for technology (Arora *et al.,* 2001) and a more strategic use of patents by firms (Rivette and Kline, 2000). Yet, open innovation can hardly be considered as a new concept with respect to its outside-in dimension. The need for firms to absorb relevant knowledge developed elsewhere had already been well documented in the economic literature long before Chesbrough's work (Cohen and Levinthal, 1989).

Open innovation is obviously a loose concept. Taken broadly, and not withholding the fact that many firms still behave in a very secret and self-reliant way, everything can be considered as being open innovation. As soon as a firm

(8) For instance, in his book, *Democratizing innovation* (2005) Eric von Hippel is very careful to draw a clear distinction between open innovation *à la* Chesbrough, which he calls distributed innovation, and open source like phenomena.

(9) Chesbrough considers open innovation as the antithesis of the closed innovation model which he defines as: « the traditional vertical integration model where internal research and development activities lead to internally developed products that are then distributed by the firm » (Chesbrough, p. 1, in Chesbrough *et al.,* 2006). More precisely, Chesbrough adds that: « Open Innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology » (Chesbrough, p. 1, in Chesbrough *et al.,* 2006).

(10) Open innovation has many points in common with other concepts developed recently by other scholars, be it « disintegrated innovation », « modular innovation » (Brusoni and Prencipe, 2003), « distributed innovation » (Kogut and Meciu, 2008; McKelvey, 1998), « dispersed innovation » (Becker, 2001) or « collaborative innovation ». All these concepts emphasise the fact that useful knowledge being increasingly dispersed, innovative activities are not the fact of one single entity but are distributed over a wide spectrum of heterogeneous actors.

does not do everything by itself (when it acquires a start-up, licenses in or out a patent, creates a spin-off, crowd-sources some of its research activities, etc.) it behaves in accordance with open innovation principles. It is therefore essential, for the sake of clarification, to situate the concept of OSI in relation to open innovation. We argue here that it is possible to rank closed innovation, open innovation and OSI on a spectrum, according to their degrees of openness and interactivity.

Closed innovation is located at the extreme left of the spectrum. It defines a framework in which knowledge is not open and firms interact little with one another. Firms are strongly self-reliant. They rely on appropriation strategies such as secrecy and exclusive IPR. Knowledge and technologies are not shared with nor made available to other firms. Furthermore, firms do not collaborate with other organizations, even selectively, for any given period of time. To use a simple metaphor, within a closed innovation environment, firms' research labs have no doors through which knowledge could flow in or out.

Open innovation is situated in the middle of the spectrum. It refers to a situation that is moderately open and modestly interactive. It is not very interactive because firms, although they allow knowledge to flow in or out, do not develop a pattern of continuous and regular exchanges. Interactions occur only at one moment in time and then stop. Open innovation is about firms that grant licenses to other firms or who create spin-offs. This concept is hence about bilateral (market) exchanges rather than community based interactions.

Furthermore, open innovation is only moderately open because in most cases, firms keep considerable control over their knowledge and technology (even though control is less tight than in the closed innovation case). Contrary to closed innovation, open innovation acknowledges the possibility of knowledge flows, but these flows are tightly controlled by firms, who continue to rely on secrecy and aggressive patenting strategies to prevent other firms from accessing their knowledge. Open innovation therefore implies permeable organizational boundaries (11). To use the same metaphor as above, it means that there is a door but this door can be open or closed according to the willingness of the firm, who still controls entries and exits.

Open source innovation, as mentioned above, lies at the extreme right of the spectrum. It is at once more open and more interactive than open innovation. It is more interactive in that firms continuously exchange knowledge over a significantly long period of time. Thus, whereas open innovation is about spot knowledge transaction, on a market of technologies for instance, OSI is clear-

(11) Indeed, Chesbrough proposed a very specific definition of openness. He used the words open and closed because in one case (the closed innovation paradigm) « projects can only enter in one way, at the beginning, and can only exit in one way, by going into the market » and in the other case (the open innovation paradigm) « there are many ways for ideas to flow into the process, and many ways for it to flow into the market » (Chesbrough, p. 2 and 3; in Chesbrough *et al.,* 2006).

ly about collective and community-based knowledge production. OSI involves community and peer production while, most of the time, open innovation relies on bilateral exchanges (in and out-licensing, merges, spin-in and out, etc.).

Furthermore, OSI is more open because firms abandon their right to control the use of the technologies they develop. They give up any possibility of controlling knowledge flows in the sense that anybody can use the knowledge once it has been disclosed. Contrary to an open innovation situation, participants in OSI projects do not rely on exclusive appropriation strategies. Therefore, while Chesbrough envisages openness as a situation in which a firm has permeable boundaries (information and technologies can come in and out but remain controlled to some extent), in OSI contexts knowledge and technology are not controlled by an owner who could arbitrarily restrict their access. For instance, one of the main, if not the main feature of FLOSS, is that anybody can access the source code. With respect to this characteristic, FLOSS are not only a distributed process, but they are also fundamentally open ; at least, far more open than what is usually meant by open innovation (Lakhani and Panetta, 2007) (12). To use the metaphor of the door again, in the case of OSI there is a door and this door is open for everybody (there may be some conditions for entering but they are reasonable and are the same for all).

To summarize, with respect to the degree of openness, it is possible to illustrate the differences between closed innovation, open innovation and OSI by considering the case of a patented technology : once a firm develops a technology and patents it, it can adopt the following strategies : (1) closed innovation : exclusivity and secrecy are preserved. The technology is not licensed at all. (2) Open innovation : the technology is eventually licensed or cross-licensed but only to some firms that have been previously selected. (3) OSI : the firm waives its right of control over the patent. Everybody can use the patented technology (sometimes in return for a reasonable fee) (Example : the Cohen-Boyer patent applied for by Stanford University, see Pénin, 2010).

IV. — OPEN SOURCE INNOVATION AND THE DYNAMICS OF INNOVATION

Isolated examples suggest that OSI can be quite successful in some cases. However, proprietary and exclusive strategies are essential features of our

(12) Lakhani and Panetta (2007) acknowledge this difference between open innovation and the open source software movement : « *OSS communities represent the most radical edge of openness* and sharing observed to date in complex technology development. *OSS communities are open in the sense that their outputs can be used by anyone* (within the limits of the license), and anyone can join by subscribing to the development e-mail list » (Lakhani and Panetta, 2007, p. 107, italics are mine). West and Gallagher (2006, p. 94, italics are mine) also conclude that : « *an open source model is inherently more 'open' than a typical R&D consortium,* both in terms of exploiting information from outside the consortium, and sharing this information back out to nonmember organizations and individuals ».

modern economies. Obviously, goods and services cannot all be produced under the open source model. Nevertheless, we believe, as Nelson (2004) does, that any innovation is somehow built upon « something » that is open and thus it is important that this « something » remains open (13). Open and closed dimensions might therefore be two complementary and equally important facets of innovation. In particular, the concept of OSI can be especially promising when it is envisaged as contributing to the development of an open knowledge platform firms can tap into in order to develop downstream applications. This point is easily understood when one considers the dynamic framework of innovation built by Callon (1993 ; 1999).

4.1. The Callon model (14)

Callon distinguishes two phases of the innovation process : an emerging phase and a stabilised phase. Whereas in a stabilised situation knowledge is easily reproducible and the primary intention of inventors is therefore to protect their inventions from imitation, in emerging phases it is the opposite. Knowledge is sticky, market perspectives are uncertain, players in the field are unknown (15). In this emergent framework, innovating firms' main objective is not to exclude other firms, but rather to include them (*i.e.* finding collaborators, suppliers, customers, financers, etc.). This need for collaboration is all the more relevant as the technology is complex and modular and network effects are strong.

This argument developed by Callon refers to an essential aspect that was underestimated by Arrow (1962) : the exploration of the conditions of development of new technologies. In order to underline the dilemma between incentives and diffusion, Arrow simplified innovation into a two-phase process : invention and then diffusion of the invention. All the aspects related to the complex dynamics linked to the genesis of the innovation were neglected thus reducing innovation to a static two-step game.

During the first step of the creation of technological trajectories, the traditional Arrovian framework underestimates the need for common knowledge between actors. For Arrow, the knowledge producer is a single individual. Nothing is said about any need for external knowledge in order to invent, nor about any community of actors that would help throughout the process of crea-

(13) Openness, sharing and freedom of use have always proved important elements of the innovation process (McLeod and Nuvolari (2006 ; 2008). Mc Leod and Nuvolari (2008), p. 15) stress for instance that : « As a final consideration, it is important not to dismiss these cases of collective invention as "curious exceptions". It is worth stressing, once more, that key technologies that lay at the heart of the industrialization process, such as high pressure steam engines, steamboats, iron production techniques, etc., were at times developed in a collective invention fashion, and consequently *outside* the coverage of the patent system ».

(14) This section is drawn from Cohendet, Farcot and Pénin (2009).

(15) This emerging phase corresponds, in a way, to what Anderson and Tushman (1990) call the « era of ferment ».

tion (the so called knowing communities). The solitary hero is therefore the only one who should be able to claim any ownership on his invention. Yet, still according to Arrow, the public good nature of knowledge decreases his incentives to innovate. The dissemination of knowledge is here considered isotropic : the diffusion of an innovation is not intended to follow a particular path. The possibility that inventors are able to choose the individuals, groups or communities with whom they will develop a common knowledge base is not recognized. On the contrary, the inventor is supposed to face anonymous actors who are looking for any opportunity to steal his creation. And this free riding behaviour can easily occur since every potential imitator is supposed to be able to reproduce the knowledge immediately at zero cost.

For Callon, this scenario can occur, but only in extreme circumstances, corresponding to stable situations in which languages and competences are already shared among the actors of innovation. The traditional framework (non rivalry and non excludability of knowledge) only prevails when the technological trajectories and languages have been developed and shared among individuals and organisations.

Callon (1999) shows that during the first phase of the creation of an innovation, when common languages and thought patterns do not yet exist, the exact opposite happens. Innovation generally occurs in an environment of strong uncertainty about the actors, their objectives, their capacities, etc. Knowledge in this context is marked by strong rivalry (it is hard to reproduce it outside the local context where the discovery has been made) and strong exclusivity (the invention is linked to the tacit knowledge of the inventor). The inventor is less likely to be faced with a free-riding or imitation-related problem than with an issue related to other actors' misunderstanding which could lead to his marginalisation (Callon, 1993). Differences in language, in cognitive models or simply the existence of a tacit dimension imply that knowledge exchanges are difficult. And the more heterogeneous the actors involved in the innovation process, the more relevant those problems of communication and exchanges.

In other words, in emerging phases, the inventor does not face a leaky knowledge problem (which would decrease its incentive to invent) but rather a sticky knowledge problem, which undermines his ability to interact with the other actors of the innovation process (16). Thus, it is necessary for the innovation actors, during the first stages of the construction of a technological trajectory, to exchange knowledge and information, to cooperate in order to develop common cognitive frames and above all to fix common objectives. Technological trajectories cannot develop unless a public or semi-public common knowledge basis was defined beforehand in order to allow for the reproduction, expansion, and development of the first creative ideas.

(16) This issue is also raised by Gibbons (1994) in his distinction between mode 1 and mode 2 of knowledge production: « In mode 2, knowledge production and knowledge appropriation converge. The outcomes are likely to be commensurate with the degree of involvement. Only those who take part in knowledge production are likely to share its appropriation » (Gibbons, 1994, p. 165).

To sum up, the first stages of innovation are complex and mostly collective processes during which actors need to exchange and cooperate. This view of innovation stands in sharp contrast to the traditional framework and its theory of knowledge spillovers, which considers that once knowledge is created, it is available for anyone to use. It is indeed the complex dynamics of evolution of technological trajectories that is underestimated in the traditional framework. The main weakness of the Arrow model is that it reduces the complexity of technological trajectories to a two-phase process. At one extreme, there is one single individual that has a creative idea. At the other lies a universe where all individuals have the same knowledge and are able to exploit the innovation. This reduction has an advantage: it draws the attention on incentive-related considerations. But it also has one major flaw: it underestimates the needs for coordination between the innovation actors, especially during the early stages of creation of an innovation.

4.2. Platform, co-opetition and incentives

Callon's view of the dynamics of innovation has important implications for open source and the strategic use of IPR. Among others, he suggests that OSI might be especially promising in upstream, emerging situations, when coordination problems exceed those related to incentives. In those contexts actors of the innovation process need less to exclude than to include and collaborate, which might explain the attractiveness of OSI in order to build common languages and knowledge bases. It is indeed in upstream situations and when trajectories are not well defined, that openness is the most valuable. As pointed out by Baldwin and Woodard (2009), the main value of openness is an option value. An open regime favours exploration and experimentation (Murray *et al.,* 2009, develop a similar argument). Thus, it is clearly more efficient when the situation (both with respect to demand and/or technology) is uncertain and unpredictable. To quote Baldwin and Woodard (2009, p. 38): « In these cases, it is not obvious what will succeed, hence the value of multiple experimentation and diverse approach is high ». This obviously suggests, and the examples we provide in this paper are in line with this view, that OSI may be especially promising for promoting the development of emerging technologies, that are relatively far from the end product market (17).

The open source production process can prove highly efficient for developing an industrial open platform (Gawer and Cusumano, 2002; Gawer, 2009) (18), which businesses can freely use in order to develop finished products. This view

(17) Note that this view of OSI is in keeping with studies that underlined the costs of strong appropriation regimes in the case of cumulative innovations (Scotchmer, 1991; 2004; Murray and O'Mahony, 2007; Pénin and Wack, 2008; Bessen and Maskin, 2009).

(18) Gawer and Cusumano (2002) argue that an industry platform provides a common foundation or core technologies that firms can reuse. They also stress the fact that industry platforms have relatively little value to users unless they are combined with in-house complementary assets. More recently, Gawer (2009) defined a platform as « a building block which acts as a foundation upon which other firms can develop complementary products, technologies or services » (2009, p. 2).

of OSI fits with a model of open co-opetition (Brandenburger and Nalebuff, 1996), *i.e.* which would not be limited to a few organizations but may potentially concern all the actors of a given field and beyond. Within OSI frameworks, firms and communities of individuals collaborate to feed an open pool of knowledge, which can then serve as a basis for corporate competition. In other words, actors of the innovation process collaborate upstream, in order to develop a solid reservoir of open knowledge, but may continue to compete on downstream markets.

Consequently, OSI may not replace corporate innovation but rather co-evolve with it. A parallel can be drawn with the linear model of innovation which considers open science as providing the industry with a reservoir of public, basic knowledge that firms use in order to do applied research (The « republic of science » vs. the « kingdom of industry », Nelson 1959 ; Polanyi, 1962). In this model, public and open research on the one hand, and corporate and closed research on the other hand, are also viewed as perfect complements. The sphere of open science is considered as a platform for industrial competition. That this model is not considered relevant anymore does not prove that openness is not important ; it only means that actors of the innovation process may have to establish new strategies to build and secure the open knowledge base into which they can tap. Thus, the preservation of openness does not only rely on public research (which increasingly tends to adopt closed strategies based on secrecy and patenting) but constitutes a challenge for all the actors of the innovation process. Many corporate actors have already understood this need to rely, to some extent, on OSI frameworks and have changed some of their behaviours accordingly.

This is particularly true in creative industries (see section 5.2 below). Similarly, the example of BiOS – detailed below – is perfectly in line with this view of OSI as providing a platform of knowledge and technology that firms can use in order to compete on downstream markets. The emergence of the airplane industry just before WWI, as described by Meyer (2010), also fits perfectly with this co-opetition model. Based on a detailed bibliometric analysis of the period 1860 to WWI, Meyer distinguishes two phases in the emergence of this industry : a pre-market phase, in which individuals did not hesitate to collaborate and share their discovery in a way that is quite similar to what happens in the case of OSI. This phase lasted until 1907. Then, when opportunities of profit became apparent and the market phase was initiated, the behaviors of the innovation actors completely reversed : they protected their discoveries by strong patents and endeavoured to divulge as little information as possible to competitors.

If OSI can contribute to develop a platform on which competitive firms may rely, it is important to investigate why firms and individuals would participate in the construction of this open platform. This is indeed an important issue in economics : why would rational economic actors be willing to contribute to the construction of a public good ? Economic literature suggests that such collective provision of a pure public good is undermined by free riding. And the larger the number of participants, the higher the incentives to free-ride. Here again, lessons from the software sector can help to understand why firms and individuals can actively contribute to build an open knowledge platform.

First, at individual level, many studies have underlined the complex mix of motivations that cause individuals to devote time and resources to developing FLOSS (Lerner and Tirole, 2001; Bonaccorsi and Rossi, 2003; Dalle and Jullien, 2003; Lakhani and von Hippel, 2003; Lakhani and Wolf, 2003). These studies, among others, emphasize that, although extrinsic motivations are important, intrinsic types of motivation dominate. And there is no reason to consider that this result is specific to software. Intrinsic types of motivation can boost individual participation in many different fields in which firms can therefore envisage to rely on a community of individuals, who can be users (von Hippel, 2005) or not. This is true in the video-game business, for instance (Cohendet and Simon, 2007), and more generally in all creative industries (Lessig, 2001). It is also true in biology, and more generally in all science-based industries, in which scientists may, for various reasons (gold, reputation, puzzle-solving), be willing to contribute to a pool of upstream knowledge (in the pharmaceutical sector for instance).

Furthermore, at the firm level, another result of empirical studies on participants' motivation in FLOSS projects is that, in many cases, individuals contribute to the projects in question during their working hours with the consent of their employers (Lakhani and Wolf, 2003). This clearly suggests that firms may also find it profitable to participate (O'Mahony, 2003). For instance, it seems that in many cases free-riding is made difficult by the fact that in order to tap into the open reservoir one needs to actively contribute to it. In particular, the absorption of the tacit dimension of knowledge requires that the firm develop close links with the community, which in turn forces it to participate. von Hippel and von Krogh (2006) therefore propose a model of « private-collective » incentives to participate, in which free-riding is limited by the specificities of the good. Firms can also base their business model on activities that are complementary to the open platform. They may rely on complementary assets that are protected (Teece, 1986). Thus, these firms can be encouraged to contribute to the development of the platform so as to add value to these complementary activities. Finally, it is also important to note that « copyleft » licenses can force some firms to release their knowledge back into the common pool, thus also contributing to the enrichment of the open platform.

To summarize this discussion, according to Osterloh and Rota (2007), firms and individuals are more willing to contribute to OSI projects if: *(i)* the learning potential is important, *i.e.* the sharing of information and knowledge leads to more than the sum of all knowledge; *(ii)* opportunity costs are low and *(iii)* the benefits are proportional to the degree of participation. Clearly, these three conditions are mostly valid in contexts that are emerging and situated far from the market. In those situations participants in OSI can build an open knowledge platform that firms can use to develop end-market products. In the next section we provide two examples that illustrate this dynamic view of OSI: we consider the case of BiOS, which is an attempt to develop open source biology for upstream research tools (Hope, 2008; Pénin and Wack, 2008) and the case of creative industries which rely on underground, creative communities in order to continuously introduce novelty.

V. — TWO EXAMPLES OF OPEN SOURCE INNOVATION

5.1. Open source biology : the case of BiOS (19)

BiOS constitutes an attempt at setting up a framework of open source biology in the field of agronomics (Hope, 2008 ; Pénin and Wack, 2008). BiOS stands for Biological Open Source. It is a sub-part of a wider project entitled BIOS, for Biological Innovation for an Open Society. This initiative was launched by Cambia (for Centre for the application of molecular biology to international agriculture), a non-profit organization (Hope, 2008).

In the domain of agricultural biotechnology, the BiOS consortium aims at developing open – easily reusable research tools. A research tool is used only for research purposes. It is not considered as an application that can be commercialized on the end-market, but it serves as a springboard for those downstream innovations (Walsh *et al.,* 2003). Research tools are therefore part of a sequential process of innovation, being situated upstream of the development of applications such as new drugs or new crops. These follow-on innovations rely on the invention, diffusion and usage of research tools. Research tools are therefore a typical example of a « platform technologies » (Pray and Naseem, 2005).

The upstream position of research tools in the innovation process in modern biotechnology makes their mode of appropriation a core issue. Since they are input into the development of further applications it is highly important that they remain easily available for reuse. Furthermore, since research tools are used for operations situated far from the end market, firms may be more willing to collaborate for their open development. Thus, research tools might be good candidates for the implementation of an open source development process. And this is exactly what BiOS endeavors to do : to develop a set of research tools in an open source environment.

Concretely, BiOS has formed a patent pool with its own patents and agrees to grant non-exclusive licenses only to those who accept the viral terms of the BiOS license. Thus, in order to use the technologies patented by BiOS, a third party has to agree to grant-back any improvements and modifications into the open patent pool. In a dynamic perspective, this creates an environment : « in which a material or invention can be improved by the ideas of many, but access is maintained for all who agree to the terms, without exclusive capture by anyone » (BiOS homepage) (20). This viral clause of licensing implies that research tools that build on a technology patented by BiOS cannot be appro-

(19) This section is drawn from Pénin and Wack (2008).

(20) http://www.bios.net (accessed [05/07/2010]).

priated. They remain available for reuse. This creates a favourable environment for collaborations, exchanges and cumulative inventions. Furthermore, although the use of a BiOS patent is open, it may not necessarily be free of charge. Private members of OECD countries are, in addition to agree to the licensing terms, required to pay a participation fee.

Yet, BiOS acknowledges that producers of downstream applications need to make money out of their investments. Thus, openness only concerns the research tools situated upstream of the innovation process, and not their downstream development. Developers of potential applications of the BiOS research tools are free to individually control new strains of plants, through patents if they so wish. This limit to openness is related to the nature of innovation in the field of biotechnology. As Maurer *et al.* (2004) have highlighted, there has to be some degree of appropriation in the innovation process so that firms have enough incentives to invest in and develop commercial applications. The development of biotech applications is costly, which means that an organization that rests solely on the decentralized contributions of a community of private, garage-based scientists with intrinsic, and limited extrinsic, motivations, is unlikely to reach the commercial success of FLOSS projects. Thus, BiOS aims at preserving the openness of the research tools without diminishing firms' incentives to develop commercial applications based on these research tools.

As yet it is unclear whether the BiOS initiative will succeed or fail. Discussions with actors in the field suggest that many firms are reluctant to participate due to the restrictive conditions of the license (especially the requirement to grant-back improvements), which is in keeping with the prediction of Gambardella and Hall's model (2006). Nevertheless the BiOS initiative illustrates the platform nature of OSI and puts forward the potential of OSI as complementary to corporate activities, thus offering firms infrastructures and technologies at a minimum cost.

5.2. The IPR dilemma in creative industries (21)

The emergence of the creative industries as one of the main drivers of growth in the knowledge-based economy has important implications for IPR and the concept of OSI. Innovation in creative industries is generally a collective effort that necessitates the interaction and coordination of a great diversity of economic actors. For instance, the production of a video-game requires the participation of hundreds, sometimes thousands of different contributors : artists, musicians, game designers, etc. Thus, when considering the question of attribution of IPR one cannot ignore the « dispersed » nature of the creation process in creative industries. Basically, stakeholders of the creative process can be divided into three broad categories : talented individuals, firms and creative communities.

Specific attention must be paid to creative communities. In creative industries firms are not backed by a regulated and institutionalized universe which could be compared to the *open science*, nor is it the result of a single individual process.

(21) This section is drawn from Bach, Cohendet, Pénin and Simon (2010).

Creative ideas emerge and develop in an informal universe that is sometimes called *underground* (Cohendet and Simon, 2007). Thus, the locus of creation is rooted in the various informal communities with which firms and individuals must somehow maintain links in order to ensure sustained innovation. By *creative communities,* we refer here to informal groups of individuals who are willing to exchange on a regular basis in order to create knowledge in a given field.

The role played by these communities in the creative process is essential: as the knowledge-based economy expands, such communities bear significant parts of the *sunk costs* associated with the process of generation or accumulation of specialized sets of knowledge. They progressively develop a common knowledge base, a model and a « grammar » (a « codebook », according to Cowan *et al.,* 2000), that will enable the creator to develop its idea sufficiently to make it economically viable. As a result, these communities are places for the accumulation of innovative micro-ideas, which may be potential sources of future creativity. In other words, creative communities are the main constituents of the « underground » from which creative industries draw their innovative power. They channel promising ideas and concepts developed underground and progressively bring them to the market.

The emergence of creative industries raises new research questions. For instance, Cohendet and Simon (2007) study the compatibility between traditional rules of corporate governance and creative communities. They show that it may be difficult for firms to manage, drive and harness creative communities without sterilising them. Another research question deals with the use of IPR: how can the three categories of actors of the creative process reconcile their different wishes and needs in terms of IPR? Basically, individuals desire strong individual IPR, firms aim at strong corporate IPR, whereas creative communities require weak IPR, or even no IPR at all, so as to be able to easily use and combine existing art, which is the raw material of creation. Creative projects can only flourish under weak IPR because they entail integrating, cutting and pasting, assembling creative elements dispersed among a vast array of technical and cultural activities carried out by diverse and distinct actors. Thus, in order to foster novelty, firms, individuals and communities must rely on some kind of open spaces (Lessig, 2001; 2004). A minimum of openness (which might not mean an absence of property) is necessary to enable creative communities to work properly.

These different logics that drive individuals, firms and communities are what we call the « IPR dilemma » in creative industries. For firms, this dilemma can be described as follows: on the one hand they need strong IPR to exclude imitators, prevent copying and therefore secure some market power. The main instruments to do so are copyrights, trademarks, patents, trade secrets, or some combination of the above. Yet, on the other hand firms also need to bring out the creative potential of the creators. And with respect to this need, a systematic use of exclusive contracts of the « work for hire » type may lead to the erosion of creativity. In this respect, it is therefore important for firms to moderate their use of exclusive IPR in order to preserve privileged links with creative communities.

To summarize, creative industries are a good illustration of how OSI (called here knowledge communities) provides a platform of new ideas that firms can use; but they also pinpoint the tensions that may arise in this particular relationship between corporate actors and underground communities. In particular, they suggest that a critical issue with respect to innovation in creative industries has to do with the strategies that are implemented to handle the IPR dilemma. Firms involved in the creative process might have to make specific arrangements in order to optimize their relationships with creative communities. For instance, firms might be forced to give up using over-aggressive strategies and to accept, to some extent, new uses of IPR, in particular those based on copyleft strategies, creative commons, etc. The two examples of the music industry and of the video-game industry studied by Bach *et al.* (2010) illustrate that IPR in creative industries can only be the outcome of a delicate balance between exclusion and openness. Developing an ongoing creative dynamic process requires the preservation of this fragile equilibrium which ensures the co-evolution of individuals, firms and a creative underground.

VI. — CONCLUSION

This paper has proposed a general definition of OSI, valid not only in software but also in other sectors, and investigated in what situations such OSI projects can emerge. Our definition rests on two pillars: openness and interactivity. OSI is both an open and deeply interactive process. Actors in OSI projects openly divulge the knowledge they produce and develop ongoing exchanges with each others', therefore favouring a bazaar mode of knowledge production (Raymond, 1999). Furthermore, we have argued that such OSI frameworks are more likely to develop in emerging phases, when needs for collaboration exceed the needs for exclusion.

This work, by proposing a clear definition of OSI, contributes to emphasizing the difference between open source-like mode of knowledge production and open innovation as defined by Chesbrough (2003). Those two concepts, although often confused as being the same, are quite different. They differ with respect to both their degrees of openness and of interactivity. In particular, most cases studied by Chesbrough do not coincide with our definition of openness because firms do not make relevant information available to all but only to a small number of partners.

OSI is a recent concept. A lot of work remains to be done both theoretically and empirically. Here are some burning questions which we believe are particularly important.

First of all, we need to improve our understanding of the dynamics of OSI. The Callon model captures the essential argument (innovation is a dynamic process that involves different phases, either emerging or stabilized) but still leaves many important questions unanswered. It tells nothing, for example, of the transition from an emerging to a stabilized situation. Similarly, it does not examine the transition from an innovation cycle to another, when emerging situations replace old and stable technologies. During those transition phases the process becomes either more closed or more open and thus the role and shape of OSI communities should evolve. For instance, at the end of emerging phases, the open source model should make way for exclusion strategies and the OSI actors should possibly turn to other projects. But, how is this transition coordinated ? What are the frictions that may emerge in this phase of change ? Who steers the process ?

Another central issue has to do with the viability of OSI in competitive contexts. The point we have made in this article is that OSI is a complement rather than a substitute for proprietary innovation. Consequently, OSI is a promising concept mostly in upstream, pre-competitive situations, since in these contexts coordination needs overcome competition effects. Yet, a more interesting step would be to explore whether or not OSI can succeed in competitive phases and under which conditions. To my knowledge there is as yet no example of an OSI initiative in such a competitive context (except software).

In relation to the above point, it will also be important, from a managerial perspective, to improve our understanding of the business models that enable firms to exploit and use the strength of OSI. Is it possible to develop business models that are fully compatible with OSI ? More modestly, is it possible for firms to develop hybrid strategies between exclusive and open access in order to reconcile their need of appropriation and of creation ? If so, under which conditions ? For instance, crowdsourcing is often presented as a hybrid strategy (a mix of strong appropriability and peer production) (Howe, 2006). Yet, we know that crowdsourcing in the case of inventive and complex activities raises many problems and is likely to work only in limited contexts (Pénin and Burger-Helmchen, 2011).

Another issue that has been neglected here but that cannot be ignored in future research deals with the practical implementation of OSI. In the real world, OSI attempts are likely to be strongly idiosyncratic and hardly implementable elsewhere without important changes. This is because in order to work, OSI must be tailored to the context and must rely on stable local communities. For instance, the design of appropriate IPR is critical and will have to be adapted to each context. Unlimited viral licenses can hardly be accepted in all sectors so that licenses will have to be tailored in such ways as to make them acceptable to all parties (de Laat, 2005).

Furthermore, the development of OSI in various sectors strongly depends on the creation and development of local communities that are in charge of elaborating and diffusing the norms which help to regulate the behaviour of all the different actors and which are therefore necessary for the development of open source innovation. Indeed, one of the first and major tasks in order to promote the emergence of OSI in a given field might be to design formal and informal rules likely to be accepted by most players and to fit the specificity of each technology. This implies that implementing OSI will require a long period of preparation and will be strongly path dependant. For instance, the success of FLOSS nowadays can to a large extent be attributed to the long lasting work of the free software foundation. Thus, since norms and rules are mainly situated within communities, the diffusion of OSI is likely to take place within communities. How rules spread from one community to another is a fundamental research question that needs further investigation.

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